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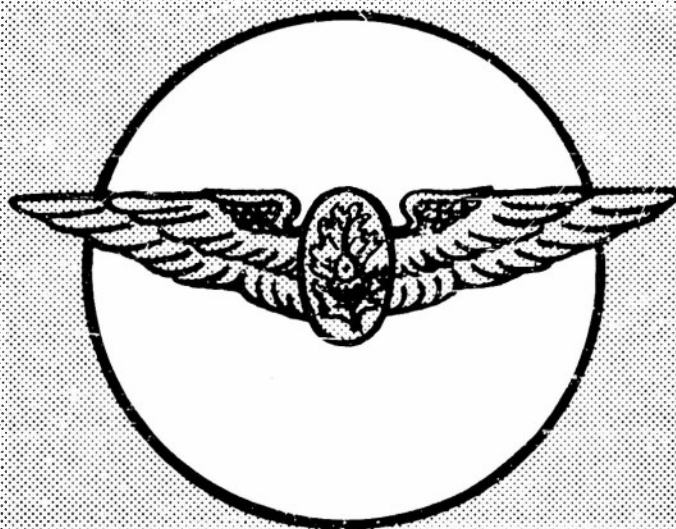
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THE EFFECT OF HIGH-PASS AND LOW-PASS FILTERING OF  
SIDE-TONE UPON SPEAKER INTELLIGIBILITY

PROJECT REPORT NO. NM 001 064.01.25



**RESEARCH REPORT**

OF THE

**U. S. NAVAL SCHOOL OF AVIATION MEDICINE**

NAVAL AIR STATION  
PENSACOLA FLORIDA

U. S. Naval School of Aviation Medicine

16 August 1954

Joint Report NM 001 004-01, Report No. 25

**THE EFFECT OF HIGH-PASS AND LOW-PASS FILTERING OF SIDE-TONE UPON SPEAKER INTELLIGIBILITY**

Robert V. Peters, The Ohio State University and Acoustic Laboratory, U. S. Naval School of Aviation Medicine, Pensacola, Florida

3 pp. 3 tables 1 illustration UNCLASSIFIED

Forty-eight speakers read multiple-choice intelligibility test lists under conditions of either low-pass or high-pass filtering of side-tone. The sound pressure level of the side-tone was kept constant for all band-pass conditions. The results indicate that speaker intelligibility improves significantly when the frequencies above 500 cps are attenuated in the side-tone circuit.

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JOINT PROJECT REPORT NO. 25

The Ohio State University Research Foundation  
Columbus, Ohio, under Contract N6ONR 22525,  
Office of Naval Research Project Designation No. NR 145-993

and

U. S. Naval School of Aviation Medicine  
The Bureau of Medicine and Surgery Project NM 001 064.01.25

THE EFFECT OF HIGH-PASS AND LOW-PASS FILTERING OF  
SIDE-TONE UPON SPEAKER INTELLIGIBILITY

Report by

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Director of Research  
U. S. Naval School of Aviation Medicine

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Captain Julius C. Early, MC, USN  
Commanding Officer

16 August 1954

## SUMMARY

Forty-eight speakers read multiple-choice intelligibility test lists (5) under various conditions of either low-pass or high-pass filtering of side-tone. The speakers' reading of the lists was heard by 298 listeners in 12 panels. The sound pressure level of side-tone for each speaker was kept constant for all band-pass conditions. The results indicate that speaker intelligibility improves significantly when the frequencies above 600 cps are attenuated in the side-tone circuit.

## INTRODUCTION

The results of previous experimentation have indicated that, as the side-tone signal for normal speakers is altered, measurable changes occur in the rate and sound pressure level of the produced speech. These measurable changes include: (a) progressive retardation in rate of oral reading under increasing increments of side-tone delay (3,6,9); (b) progressive increase in sound pressure level of oral response under increased side-tone delay (3,6); (c) an increase or decrease in the sound pressure level of response as the sound pressure level of side-tone is increased or decreased (4,7); and (d) an increase in oral reading rate under accelerated transmission time of the external side-tone. Results concerning the effect of an altered side-tone signal upon the intelligibility of the speaker have heretofore been inconclusive (1).

The above results, indicating that speakers respond to changes in time and sound pressure level in the side-tone circuit by altering their rate and sound pressure level of response, suggested that changes in the side-tone signal which would be occasioned by band-pass frequency filtering of the signal might result in measurable changes in speaker intelligibility. Under certain frequency-filtered conditions the relative lack of intelligibility of the side-tone signal might cause the speaker to become more intelligible in his response. The present study was concerned with the effect of low-pass and high-pass frequency filtering of side-tone upon speaker intelligibility.

The hypothesis under test was that there is no difference in the intelligibility of speech obtained with speakers reading under: (a) six conditions of low-pass frequency filtering of side-tone and (b) six conditions of high-pass frequency filtering of side-tone.

## PROCEDURE

Forty-eight speakers read all the speaker lists from either Form A, B, A-1, or B-1 of the multiple-choice intelligibility tests (5). Each speaker read two lists under each of the side-tone band-pass conditions. Half of the speakers read under low-pass filtering conditions and half under high-pass filtering conditions. The order of presentation of the conditions was randomly varied from speaker to speaker. The subjects who participated in



the experiment were drawn from a population of cadets in the Naval Aviation training program.

The side-tone band-pass cut-off frequencies were 150, 300, 600, 900, 1200, and 1500 cps for high-pass filtering and 300, 600, 900, 1200, 1500, and 1800 cps for the low-pass filtering.

These side-tone conditions under which the speakers read were achieved through placing a variable band-rejection filter and step attenuator in the system which fed the side-tone signal to the speaker. Adjustment of attenuator settings permitted a relatively constant sound pressure level of side-tone to be delivered to the speaker's ears throughout the range of filtering conditions. Attenuator settings for the various conditions were determined by obtaining subjective judgments on equal apparent loudness of the band-pass conditions from three pre-experimental subjects. Parallel placement of two VU meters, one in the source pick-up system from the speaker and the other in the side-tone channel system, allowed further control of the constancy of side-tone signal level during experimental sessions. The sound pressure level of the side-tone signal at the speakers' ears through Permoflux PDR-8 receivers was approximately 80 db (re 0.0002 dynes/cm<sup>2</sup>). The speakers read under conditions of quiet. Source pick-up of the speaker's voice was by a condenser microphone (Altec-Lansing, model 21C), boom-mounted, adjacent to the corner of the speaker's mouth.

The listeners received the voice signal at a level of approximately 95 db (re 0.0002 dynes/cm<sup>2</sup>) through Permoflux PDR-3 receivers under a free-field environment of 114 db of recorded propeller type aircraft noise.

Each speaker read 12 intelligibility lists for the listening panels. Two lists were read under each side-tone condition. The mean intelligibility value for each speaker on the two lists was used as the basic score for the statistical treatment of the data. The data were treated by double-classification analysis of variance. Where F-ratios were found which exceeded the five per cent level of confidence, the statistic t was used to establish the "critical difference" between the means.

## RESULTS

A summary of the results of the analyses of variance relative to intelligibility values for speakers reading under the high-pass and low-pass frequency filtering of side-tone are shown in Table 1. The variance attributable to high-pass side-tone conditions did not reach the five per cent level of confidence, although a comparison of the means in Table 2 indicates that there is a tendency for speakers to be less intelligible as the cut-off frequency of the side-tone signal for high-pass filtering is increased in the range from 150 to 1500 cps.

The variance attributable to conditions of low-pass filtering of side-tone, as indicated in Table 1, exceeds the five per cent level of confidence. A comparison of the means shown in Table 2 indicates that speakers were

significantly more intelligible when frequencies above 300 and 600 cps in the side-tone signal were attenuated than they were when the cut-off frequency for low-pass filtering was in the range of 1200 to 1800 cps. A further comparison, shown in Table 3, was made between the values for three of the low-pass conditions and the 150 cps cut-off high-pass condition, assuming that the latter condition represented essentially a nonfiltering condition. Beginning with the low-pass cut-off of 300 cps, the differences between the mean of the 150 cps cut-off high-pass condition and each successive low-pass condition were tested with the statistic ( $t$ ) to determine the significance of the difference, until a ( $t$ ) was found which was not significant. Significant differences between the means of the low-pass conditions and the mean for the condition of 150 cps cut-off high-pass filtering were not found beyond the 600 cps cut-off frequency of the low-pass side-tone filtering condition.

Mean intelligibility curves for the speakers reading under the high-pass and low-pass frequency filtered conditions of side-tone are graphically portrayed in Figure 1. The mean intelligibility of the speakers is seen to increase as the low-pass cut-off frequency of the side-tone signal is lowered. No consistent relation is established between the mean intelligibility values and the conditions of high-pass frequency filtering of side-tone.

### DISCUSSION

The hypothesis that no difference exists in the intelligibility of speakers reading under different conditions of low-pass frequency filtering of side-tone may be rejected at the five per cent level of confidence, while the hypothesis pertaining to high-pass frequency filtering of side-tone cannot be rejected on the basis of the results of this study. Assuming that the sound pressure levels of the side-tone signal remained sufficiently constant to satisfy the requirements of the experiment, and that any differences found may therefore be attributed to frequency components present in the side-tone signal, the generalization may be made that when the frequencies above 600 cps are attenuated in the side-tone channel, an increase in speaker intelligibility may be expected to occur. This increase in intelligibility may result from the speaker's attempts to improve the precision which appears to him to be lacking in his own speech when the side-tone signal frequencies above 600 cps are attenuated.

### SUMMARY

The results of previous experimentation concerning the human speech feedback circuit have indicated that measurable changes occur in the rate and sound pressure level of response as the perceived side-tone characteristics are altered. The present experiment was concerned with the effect of band-pass filtering conditions of side-tons upon speaker intelligibility. Mean intelligibility scores of speakers were found to increase when frequencies above 600 cps in the side-tone channel were attenuated.



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Table 1. Summaries of analyses of variance relative to speaker intelligibility under six conditions of high-pass frequency filtering of side-tone and six conditions of low-pass frequency filtering of side-tone.

<u>Source of Variation</u>	<u>d.f.</u>	<u>Variance</u>	
		<u>high-pass filtering</u>	<u>low-pass filtering</u>
Side-tone conditions	5	45.82*	69.63**
Speakers	23	919.59	366.75
Remainder	115	24.15	26.76

\* F, 1.85 < 5%

\*\* F, 2.60 > 5%

Table 2. Mean intelligibility scores of speakers reading under: (a) six conditions of high-pass frequency filtering of side-tone and (b) six conditions of low-pass frequency filtering of side-tone.

<u>Side-tone conditions</u>	<u>cut-off frequency in cps</u>						
	150	300	600	900	1200	1500	1800
<u>Scores %</u>							
(a) high-pass	72.8	72.9	69.4	70.3	70.9	71.0	
(b) low-pass*		76.9	76.6	74.1	73.8	72.9	73.2

\* Any difference between two means of 3.10 significant (t) at the 5 per cent level of confidence.

Table 3. Mean speaker intelligibility values under conditions of low-pass side-tone cut-off frequency of 300, 600, and 900 cps compared to the mean speaker intelligibility value under the high-pass side-tone condition of 150 cps cut-off frequency.

<u>Side-tone condition</u>	<u>150</u>	<u>300</u>	<u>150</u>	<u>600</u>	<u>150</u>	<u>900</u>
Score %	72.8	76.9	72.8	76.6	72.8	74.1
(t)	1.34*		1.32*		3.33	

\*Significant (t) at the 20 per cent level of confidence.

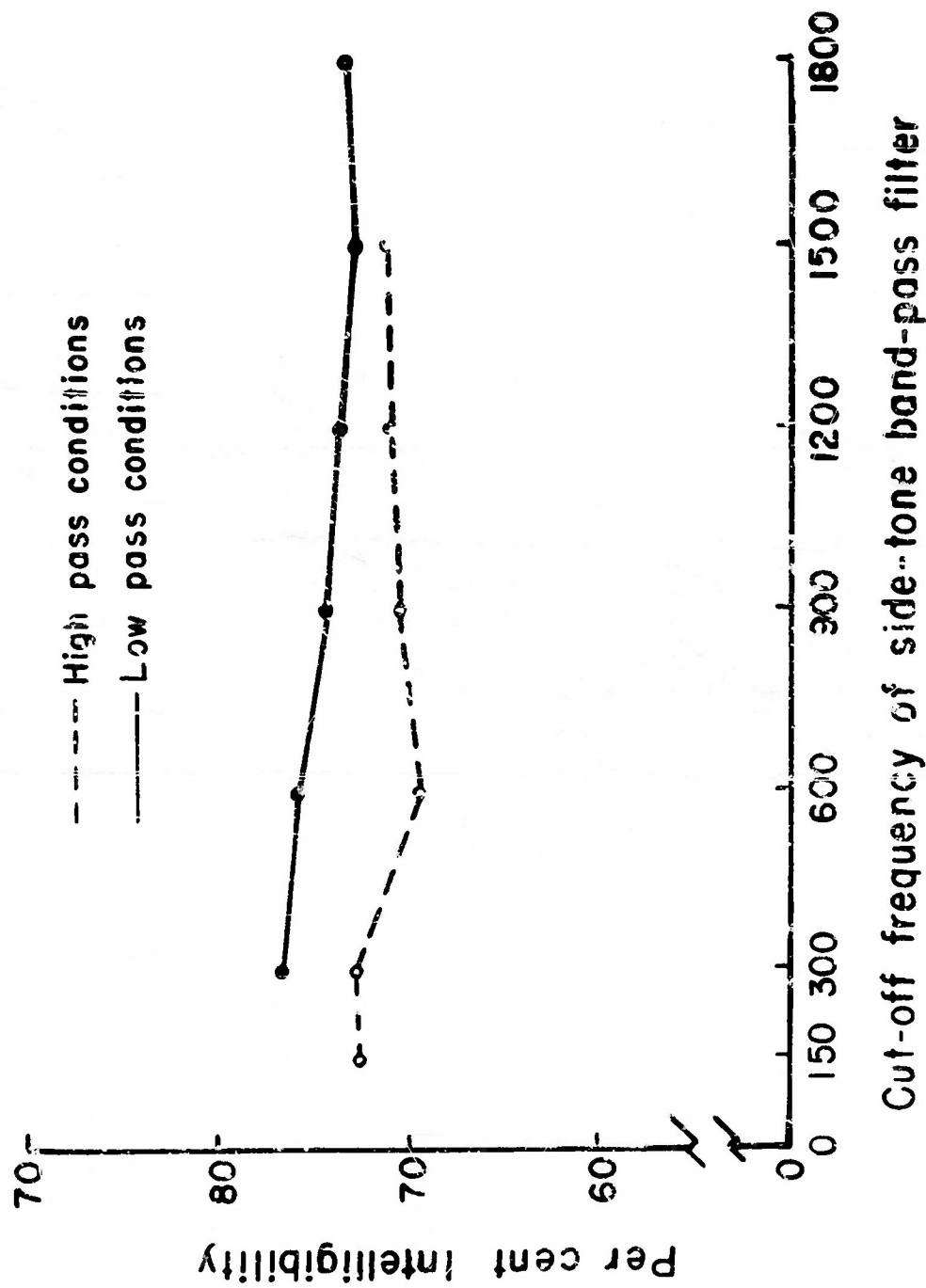


FIGURE 1. MEAN INTELLIGIBILITY OF SPEAKERS READING UNDER SIX CONDITIONS OF HIGH-PASS FREQUENCY FILTERING OF SIDE-TONE AND SIX CONDITIONS OF LOW-PASS FREQUENCY FILTERING OF SIDE-TONE.

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